Advancements In Digital Radiography: CR, DR, and DICONDE

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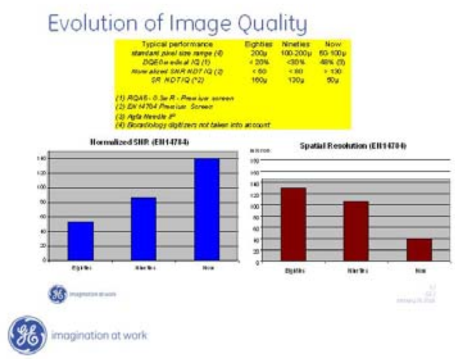
Introduction

Imaging in today's digital age requires knowledge of the various detection methods and the effect the detector's attributes have upon image quality. There are numerous different modalities and many of these are best suited for a particular application. The application will determine which digital technology should be chosen. Basic questions, such as the need for portability, throughput, desired image quality and cost, must be considered and answered. The scope of this presentation is intended to provide an overview of where digital technology has proven to be cost effective and very successful from an image quality and productivity prospective. A digital solution has two or three main components: the image acquisition component (can be one or two parts) and the reviewing component with the soft ware. This last one is extremely important, as this brings the differentiation to film.

Short Historical Evolution

Over the last 3 decades the image quality, speed, and functionality of digital systems has increased tremendously. The spatial resolution and the signal to noise ratio have improved thanks to better image plates and better scanners. In concert data analysis tools have improved in parallel with the hardware evolution. Today there are various software packages available to acquire, review, share, and store date electronically. Some packages are fully DICONDE compliant to ensure data integrity. A big evolution has been done in medical but the ultimate step became real once specific NDT equipment and plates became available. It is amazing and unexpected that the image quality requirements in NDT are more stringent than in medical. The advantage of NDT is that the X-Ray or isotope dose is much less important than in medical applications, which provides flexibility to develop specific NDT solutions.
The improvements on the imaging plates side are around top coat improvements and grain size homogeneity. On the scanner side it is about light collection efficiency and pixel size control.



Common Misunderstandings & Misperceptions

For Computed Radiography sometimes people are confused about laser spot size and pixel size and think that a smaller laser spot size automatically will give rise to a higher spatial resolution and consequently to a better POD (probability of detection). Due to the specific characteristics of a laser it is very important to give the definition of the laser spot. Three different definitions can be used and each of these gives a different value of the laser spot size! Other effects influencing the spatial resolution are the spreading out of the light on the top coat and the phosphor layer and the afterglow effects. It is clear that one figure cannot describe the capabilities of a digital system. Next to the spatial resolution we must look at the SNR as this will also strongly influence the POD. The main contributor in the SNR is the phosphor plate.

For Digital Detector Arrays (DDA) a common misconception is that pixel pitch is equal to detector resolution, Although pixel pitch is the foundation in determining resolution, there are other influencing factors such as geometric un-sharpness, thickness and properties of the scintillator and various sources of scatter that may degrade the modulation of the features in the image.. It is important to consider basic spatial resolution, not pixel pitch when determining the overall capabilities of the POD of the chosen system.

For all this reasons manufacturers can have their solution certified by an independent party (e.g. BAM in Germany) and this give already an indication about the capabilities of the solution proposed. Of course a site demonstration tailor to a specific application is always the ultimate test to see whether a solution fits the purpose.

Factors that Impact Radiographic Solution Selection

Several factors influence the decision to purchase a radiographic system. These include image quality, the range of applications the detector will be used, the accessibility of the device into the location under examination, the speed requirements for the range of applications, artifacts prevalent with the devices, costs to purchase and operate the device and the associated infrastructure, and available standards to assure consistent industry results. Embedded in this discussion are radiation safety issues and environmental concerns such as temperature and risk to damage through impact or shock that are typically encountered in field testing or open environment (no enclosed shielding) testing.

Image Quality

In nondestructive testing, as in medical imaging, the quality of an image to achieve the required detection capability depends on the image signal to noise ratio within an object and the spatial resolution associated with that image. A metric that best defines the overall performance and efficiency of a detector system is the detective quantum efficiency (DQE), which includes the signal, noise, spatial resolution and required exposure level. If a wide range of inspection applications and high-speed imaging and throughput are of dominant interest, the device with the highest detective quantum efficiency is then the desired choice. But frequently, one of these three parameters (speed, contrast or spatial resolution) can be relaxed in order to achieve either higher performance in the other two, or obtain some other benefit in system selection, such as a lower cost. Digital radiographic detectors based on amorphous silicon detectors have high detective quantum efficiency because a high gain scintillator or photoconductor absorbs, converts and efficiently transfers much of the x-ray energy to the amorphous silicon readout device. The biggest draw back of these systems is the rigidness. The application engineer must decide which factors are most important for the business at hand. Once a system approach is selected, that system must be tested under expected inspection conditions to validate that the system meets desired solution

Range of Applications

Many industries require a wide range of materials and thickness to be inspected within a factory or in the field. This may require the x-ray energy to span a range of low kilovolts to several MeV-to penetrate such diverse materials as composite flight control surfaces to steel landing gear. It would be convenient if the detector could be configured to operate within this range as needed. Film, DR and computed radiography detectors have been successfully used in this range. In a similar vane, the use of a range of gamma ray sources of varying energies and activity may need to be accommodated by the detector system. In many cases, the activity of an isotope is selected so that they can be used within a limited radiation safety zone. This then requires the detector system to be very sensitive and/or have the ability to allow long exposures, so that the signal rises well above the noise floor of the device. Although DR systems have excellent DQE and sensitivity, dose is important~~.~~ In circumstances, where a DR detector can provide good image quality, their selection will be preferred for the increased speed, and the immediate availability of the image. Yet other applications require the use of micro focus x-ray techniques to detect very minute defects, typically less than 25 microns (0.001-in). In this case, sensitivity is a top priority and DR systems, both static and real time offer significant speed advantages. Although film techniques can be used with a micro focus x-ray tube, DR systems have been shown to operate in real-time achieving a spatial resolution better than 10 microns (0.0004in) using these tubes and a rate of 30 frames/sec. Some of these devices also offer the capability to perform static imaging or image averaging to achieve better sensitivity. For example once a defect or a feature has been identified, a longer exposure of that area can be obtained to increase the signal to noise ratio and improve defect analysis.

Inspection Accessibility

Many applications have limited access such as inside a complex casting, or inside jet engines. Yet other applications require large coverage, but over a curved surface. In other specialized examinations, small detectors are required to gain access. In these cases, film and CR systems are the preferred method because they can be configured to fit inside these areas and can be shaped or cut to meet the application. Although small area DR systems are coming online, their performance has not yet been verified for these applications, they have limited area, and are not flexible. Some large area DR systems are quite thin and can be used where other environmental issues such as high temperature, impacts or other forms of shock are not present.

Total Speed of Inspection

The speed of acquisition has already been discussed above. The ultimate critical factor for some businesses may be the overall speed to results and interpretation. In production lines, or in field applications where limited time is available to get successful exposures, it is necessary to have the correct answer before moving to another location. In these circumstances, for example where films or CR image plates are not “plastered across a structure”, real-time or near real-time results fully impact the time and cost not only of the inspection itself, but also to the surrounding processes. For example, work on an aircraft is usually halted during radiography. During many radiographic examinations, one particular radiographic set-up cannot be moved until an approved exposure and results are obtained. If using film, or even in some cases a CR plate, it may take several minutes to process the image before knowing if further exposures would be necessary in that local area. In these circumstances, it may be more cost effective to use fast DR systems where results are obtained almost instantaneously. This enables related processes on a structure to get back on-line more quickly, thus enhancing overall maintenance productivity.

Lifetime/Artifacts.

All detectors from film, to CR to DR panels can have artifacts. With film, creases or minor bends on the film manifest themselves as false indications on the resulting processed sheet. In these cases, if such an artifact appears, the level 3 might request a new film be exposed. Similarly, CR plates can develop nicks and scratches that typically cannot be corrected in the final image. At this point, it might be prudent to retire the screen and place a new one in service. DR detectors are less prone to damage in this vane as they are protected by cover sheets, but can develop artifacts from radiation damage or bad pixels In these cases, the cost benefit of fast digital data must be weighed against replacement or service costs. Another artifact that may be present in digital images is ghosting. This artifact occurs when a phosphor retains a history of prior radiation and is revealed in the current image or real time sequence. Ghosting can provide false positive indications or might even hinder the detection of true positive indications.

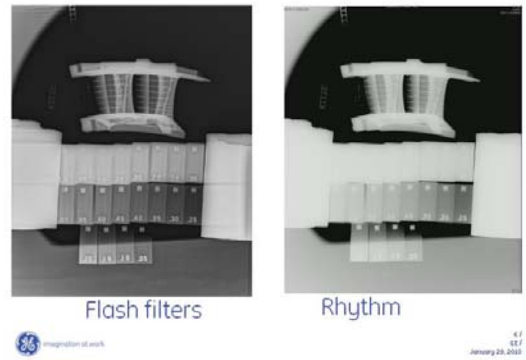
Purchase Cost and Inspection Cost.

A typical means to justify a purchase cost is to determine how fast the system will pay for itself considering future operating costs. Other factors come into play. Are there existing radiographic cells and other infrastructure. Is there upfront capital to make the change? In comparing whether to purchase a film, CR or DR system, are darkroom facilities preexistent, what about local environmental specifications~~.~~ The cost/benefit tradeoff of digitization and rapid dissemination of information needs to be considered in this discussion as well. These factors as well as maintenance and other recurring costs need to be considered and weighed against the discussions in the above sections. It is best to have both technical and financial analysts on the team to weigh all of these options. The total cost of ownership is key!

Industry Standards.

Over the decades that NDT film has been in use, a series of international standards have been devised to accommodate every aspect of film radiography, from film processing standards to image quality to calibration of film densitometers. In the areas of CR and DR, only recently have standards been introduced. What is needed is to obtain a full slate of standards that deal with the same issues that film standards have dealt with, from acquiring and processing the images, to assuring adequate image quality to dealing with new issues such as bad pixels and other artifacts. Until these standards can be implemented, it is up to the cognizant purchasing engineer and the NDT system supplier to address these issues on an individual basis. In some industries, the lack of standards prohibits the purchase of new technology. In selecting a system, it is best to fully understand what the industry or individual company specifications dictate for standards compliance prior to getting too deeply entrenched in all of the above discussions.

Software



Software is a key element for all digital solutions and brings the differentiation with film. More tools are available which enable the user to communicate faster and to enhance images using window leveling and wall thickness measurement is automated and more accurate. Complex mathematical analysis methods can be used with little effort for the end user.

Filtering is a tool, which is used to enhance the image but with the disadvantage of slowing down the work flow. This filtering and window leveling takes time by the observer to find the optimal conditions. Recently GE Inspection Technologies developed a fully automatic filter that gives the end user the optimal image with just one mouse click. The two requirements are fulfilled at the same time: fast workflow and optimal image quality. This unique solution is specifically developed for castings and welds but shows very good results in erosion corrosion applications. Data archiving and data sharing has also become easier with the evolution of the software platforms.

Functionality exists today in concert with the traditional acquire and viewing functions to enable users to easily store data and share data across the worldwide web. This provides a very powerful solution for customers who retain large amounts of data and has the need to share the data across multiple people and locations.

The DICONDE format ensures that all information is kept and can always be found back on any computer with which people are communicating internally and / or externally. DICONDE compliancy ensures that operators are not limited by current proprietary formats, eliminating the need for future data conversion and simplifying data integration from other NDT information sources, such as pipe management databases. This ensures that customers can choose the best-in-class hardware and software platforms, while always ensuring the reliability of their data and its format.

DICONDE based software platforms also allows one to manage all inspection data; Radiographic, Visual, Ultrasonic, Eddy Current, etc. on one platform and allows quick efficient sharing of inspection data and information.

The phrase “a picture is worth a thousand words” comes true with DICONDE; the image and all the key information about that asset and inspection are stored right with the image. This provides a standard structure for querying on images and provides the opportunity for advanced trending and data analysis based on inspection history ultimately leading to better asset management and improved asset uptime.

Conclusions

Digital X-Ray products continue to be the future in replacing traditional film applications. As technology continues to advance around IQI requirements, speed, and data analysis the cost advantages and the flexibility in applications will out pace film. In concert with technology industry standards will continue to evolve and become more formal providing a benchmark of acceptability criteria for the industry.